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HUMAN ENGINEERING LABORATORY
AVIATION SUPPLY CLASS III/V MATERIEL (HELAVS III/V)
FIELD TEST

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INTRODUCTION

In order to maintain aviation assets at a maximum capability, it is imperative that aircraft returning from missions be returned to their "mission ready" status as soon as possible. One aspect of this issue is the ability to rearm and refuel those returning aircraft. This issue is currently addressed by the concept of Forward Arming and Refueling Points (FARPs). FARPs, which will be established close to the forward line of troops or battle area, will preclude the need for aircraft to travel to rearward areas for this purpose, hence saving valuable mission time.

To this end, the US Army Human Engineering Laboratory (HEL) has embarked upon developing a data base related to the personnel and equipment issues in supplying and loading fuel and ordnance onto helicopters in forward areas. Efforts in this project were initiated in 1977 with background studies on FARP methodology and operation. Contact has been established and maintained with the Directorate for Combat Developments, US Army Aviation Center, Fort Rucker, Alabama, on the operation of aviation Class III/V materiel distribution. A coordination meeting was held to exchange information and ascertain priorities on developing data for aviation Class III/V materiel. As a result of this meeting, it was determined that loading of fuel and ordnance on gunships was the highest priority. Data on the refueling and rearming of the AH-64 is of particular importance since very little information is available in this area. Results of this field experiment will help establish a data base and provide inputs to field studies currently under consideration.

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OBJECTIVES

The experimental objective was to obtain human performance data on helicopter refueling and rearming procedures. The data consisted of time measurements while refueling the helicopter and rearming the HELLFIRE missiles and 2.75-inch rockets. The experiment addressed the effects of crew size, day/night operations, and chemical/biological protective equipment on the refueling and rearming operations.

A second objective was to develop test methodologies which could be applied to the Aviation Performance Assessment in a Chemical Environment (APACHE) field study.

An additional objective was to evaluate the Division '86 Table of Organization and Equipment (TOE) staffing levels related to FARP operations. This data will assist the US Army Training and Doctrine Command in developing realistic TOEs for future attack helicopter units.

METHODOLOGY

Subjects

Participants in the experiment were male soldiers from the Materiel Testing Directorate, US Army Aberdeen Proving Ground. The military occupational specialties (MOSs) of those personnel differ from those found in the field performing FARP refueling and rearming operations. In order to alleviate this difference, each subject received extensive training in the specific duties to be performed during the evaluation.

Experimental Design

The experimental design was a completely random factorial (pqr) design with the dependent variable being task time. The three- and five-man crews were composed of randomly assigned individuals. The eight experimental conditions were as shown in Table 1. There were twelve trials for each of the eight experimental conditions. The order of presentation of each of the conditions was established through the use of a table of random numbers.

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TABLE 1. Experimental Conditions.

3-Man Day CB	3-Man Day No CB	3-Man Night CB	3-Man Night No CB
5-Man Day CB	5-Man Day No CB	5-Man Night CB	5-Man Night No CB

PROCEDURES

Subject Training

Subjects were required to perform each specific task assigned until asymptotic efficiency was achieved as measured by the time to complete each task. The training required to reach the asymptotic level is shown below in the order administered:

- A. Day, No CB - Twenty-four runs
- B. Day, Full CB - Eight runs
- C. Night, No CB - Ten runs
- D. Night, Full CB - Eight runs

Training runs were conducted with three-man and five-man crews. The need for detail such as removal of 2.75-inch rocket shorting clips, proper handling of missiles, and safety checks was emphasized.

Initial Conditions/Assumptions

- A. The following assumptions were made concerning ammunition:

- 1. HELLFIRE missiles are in closed but unlatched containers.
- 2. 2.75-inch rockets are in 19-unit containers or stacked on the ground.
- 3. Returning aircraft require full armament loads.
- 4. There are no malfunctioning missiles or rockets; i.e., rockets or missiles do not have to be off-loaded.

- B. The following assumptions were made concerning refueling and grounding:

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1. The Forward Area Refueling Equipment (FARE) systems are mounted on 5-ton trucks.
2. At least four full-fuel bladders containing JP-4 fuel are available.
3. Attack helicopters require 1500 lbs of fuel per mission at 6.56 lbs/gal.
4. All grounds are established; i.e., conductive.
5. Sufficient grounding rods and wire are within the unit.

C. The following assumptions were made concerning materiel and Class V loading:

1. Adequate Class III/V materiel and sufficient materiel handling equipment (MHE) are available.
2. Class III/V materiel will be positioned near the aircraft.
3. The five-man crew loading procedure would be to load all missiles first and then the rockets to preserve mission readiness.
4. The three-man crew loading procedure would be to load the left side armament first, the missiles next, and then the rockets to preclude interference with the fueler.
5. The HELLFIRE missiles are loaded in the sequence (upper inboard, lower inboard, lower outboard, upper outboard) per draft TM 9-1427-475-23.

D. The following assumptions were made concerning personnel:

1. The refueler is a 76W; the rearmer are 68Js and/or 68Ms.
2. Personnel perform only those tasks specified by their MOS.
3. Personnel from the three-man or five-man crews will not undertake supervisory or battle damage assessment tasks.

E. Additional assumptions:

1. The FARP is laid out before the arrival of five attack and three scout helicopters.
2. There is sufficient maneuver space within the FARP.
3. CB gear is sufficient for the threat.
4. No hardware flaws occur.
5. No maintenance is to be performed.
6. Night lighting (chemical wands) would be sufficient.

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RESULTS AND DISCUSSION

Results

All data runs, both day and night, were recorded on cinema film at four frames per second. The specific task times were obtained by evaluation of those films after all trials were completed. In addition, overall trial times were obtained through the use of handheld digital timers.

By summing the mean percent change in time for each condition (dependent variable), the mean change in task time is obtained. The following general conclusions can be derived:

A. There was a 44-percent reduction in task time when a crew of five performed the rearming and refueling task as opposed to a crew of three.

B. There was an 11-percent increase in task time when the crew wore CB protective gear.

C. There was a 38-percent increase in task time when the rearming and refueling task was performed at night.

These effects were statistically significant at the 0.01 confidence level.

Table 2 shows the individual ordnance loading times. These times do not include any of the subsystem checks and related tasks and represent the time spent handling and loading munitions.

The greatest effect on the task times is the result of increasing the crew size to five people. However, across all conditions, the task times were affected more by having to perform tasks at night than by having the crew wear CB protective clothing. Significant interactions were evident, but they did not alter the conclusions drawn from the experiment.

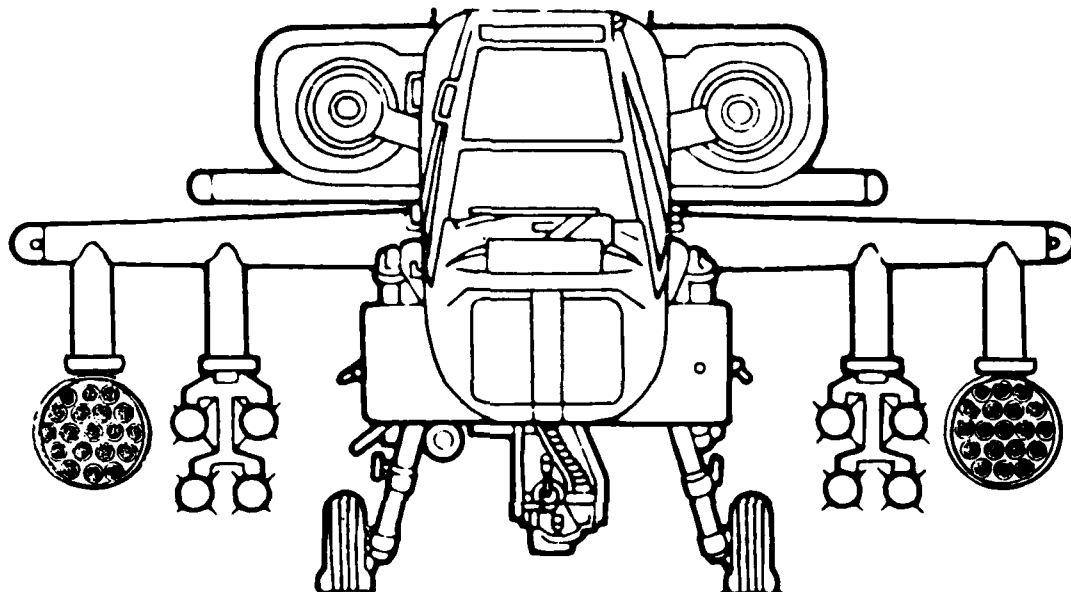
DISCUSSION

Analysis of the data in Table 2 indicates that the mean time to load the left- and right-wing stores differs. The exact reason for this difference is not readily apparent but may be due to a number of reasons, including how the rockets were positioned, the type of missile shipping containers used to hold the missiles, and the presence of the 30mm loading equipment.

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TABLE 2
Individual Ordnance Loading Times by Sides (Minutes)



Right Rockets	Missiles	Conditions	Missiles	Left Rockets
<u>Three-Man Crew</u>				
2.38	2.11	Day without CB gear	2.11	2.30
2.76	2.40	Day with CB gear	2.65	2.76
3.24	2.91	Night without CB gear	3.49	3.12
3.42	3.25	Night with CB gear	3.32	3.34
<u>Five-Man Crew</u>				
2.63	2.06	Day without CB gear	2.56	2.07
2.61	2.50	Day with CB gear	2.29	2.52
3.44	3.06	Night without CB gear	3.33	3.06
3.32	3.34	Night with CB gear	3.60	3.32

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The ordnances to be loaded were positioned by placing the rockets on either side of the missiles, which were in the center. The nineteen rockets for left-side loading were housed in a circular container which was slightly elevated at its opening; while the rockets for right-side loading were stacked on a five-inch high pallet. The left-side rocket loading times, which were less than the right-side rocket loading times by approximately 6 percent, indicate that the use of the circular container and how it was positioned may have reduced the overall loading time.

The missiles for left-side loading were stowed in four of the newer metal containers which had been used for qualification tests and were slightly damaged. The missiles for right-side loading were stowed in three wooden shipping containers and one older fiberglass container. An analysis of the data indicates that the left-side loading times were approximately 8-percent greater than the right side. That difference may be attributed to the difference in container types.

Since one of the premises for the investigation was that the missiles would be readied for loading with "unlatched" containers, the above result would be more meaningful if a "latched" container condition could be obtained from the results. Therefore, a short investigation was accomplished to obtain the missile extraction times from latched containers. Again, the data from Table 2 was used but was now modified by subtracting extraction times from wooden and unlatched metal containers and adding the extraction times from latched containers.

These new times slightly affected the results, with the left-side missile loading times being an average of 7-percent higher than the right side. Therefore, a condition must have existed on the left side which caused this anomaly, as it was not expected. When the data films were reviewed, the only observed difference was that the metal containers' three-foot positioning arm was swung into the open space between the containers. While it cannot be stated with certainty, the missile positioning arm may have caused the difference in data since the 30mm loading equipment would have increased the right-side loading times.

Because the fuelers had, in most cases, completed their tasks before the three-man teams started to load the right-side missiles, a comparison of the right-side loading times gave some indication of the interference between the loading crew and the fueler. As a result, the fuelers' presence increased the crews' missile loading times by an average of 2 percent.

The correlary question to whether the fueler interfered with the ordnance loading was: "Did the ordnance loaders interfere with the fueler?" The fueler's activity time, either walking to and from the

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- aircraft or preparing and securing fueling equipment, decreased an average of 3 percent when a five-man crew was employed. It was presupposed that the presence of two ordnance loaders on the right side would present an interference to the fueler with a resultant increase in task time. However, in consonance with the loader times, the fueler took an average of 15-percent longer when wearing CB gear and 25-percent longer when performing the task at night.

→ OBSERVATIONS

During the investigation, observations were made related to the rearming and refueling process. They are offered here with suggested improvements where appropriate.

→ Auxiliary Night Lighting

The initial experimental procedure called for the crews at night to use individual chemical illumination wands. These light sources provided illumination which was thought sufficient for the loading task without compromising the security of the area. However, after the first few night trials, the crews chose not to use them, as they presented a localized glow which interfered with their vision when brought adjacent to discrete areas requiring more illumination. In addition, the light wands could not be conveniently carried or positioned to provide sufficient lighting.

Missile Handholds

When the missile is exposed in its shipping container, it can not be extracted from the lid side or aft end of the container. As a result, the loader lifted the missile out either by grasping the aft attaching shoe or by grasping the two top fins. In similar fashion, the second loader either lifted the missile out by cradling the optical seeker head or by grasping the forward attaching shoe. The HELLFIRE contractor indicated that the shoes should be able to take the strain, but preliminary loading procedures obtained from draft TM 9-1427-475-23 specify that the optical seeker head, attaching shoes, and fins are not suitable for lifting points.

If these points cannot be used for lifting, some type of handholds should be provided, not only for lifting but also for attaching the missiles to the launch rails.

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Missile Attaching Procedure

The missiles have been designed to allow the missile to drop free of the launcher rails in a zero velocity launch situation. Specifically, the aft attaching shoe is narrower than the other two; and when the missile is fired, the aft shoe drops from a slot in the rails at the same time the middle shoe clears the forward end of the rails. Although this facilitates the launch procedure, it increases the complexity of loading the missile onto the launcher. The attachment procedure is more difficult than simply pushing the missile back onto the rails. The procedure prescribed by the contractor is for the loader holding the aft end of the missile to position the aft shoe in the slot in the rails while the loader holding the forward end of the missile rotates the missile axially to align the middle shoe with the rail opening, which aligns all attaching shoes and allows the missile to slip onto the rails. This has to be accomplished with the middle shoe approximately 1/4-inch forward of the launcher rail opening. The difficulty in this procedure is that during both day and night loadings, the aft loader cannot see the slot in the rail. Also, during the night, the forward loader cannot see to correctly align the middle attaching shoe.

Three suggestions are offered which might enhance attaching the missiles to the rails. Initially, provide a high contrast legend or decal on the side of the launch rails to indicate where the aft attaching shoe is to be placed. Secondly, mark the locking handles so they can be seen at night. Finally, chamfer the attaching shoes so that they slip onto the rails when precise alignment has not been obtained.

Training Missiles

During the investigation, each training missile was up- and down-loaded approximately 150 times. As crew training was progressing prior to actual test runs, it became evident that each attempt to attach the missile to the rails when slightly misaligned caused the aft edges of the attaching shoes to deform, preventing the missile from slipping onto the rails easily. Consequently, the attaching shoes had to be filed during testing to true up the shoes.

Providing a chamfer on the aft edges of the attaching shoes, as suggested earlier, should reduce, if not eliminate, this condition. It should be noted that this condition should not occur with the actual missiles which are normally only loaded once.

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Rocket Handling

During the investigation, the loaders were allowed to develop their own rocket-carrying technique. There were two common procedures for rocket carrying. The first was for each loader to carry a single rocket and insert it into the launcher, taking turns until all 19 rockets were loaded. The second procedure was for one loader to pick up a single rocket and carry and transfer it to a second loader who then inserted it into the launcher. As these types of procedures were left up to the individual loader teams, no times were obtained as to which procedure was faster.

In addition, it should be noted that the longer rockets were used; and, as such, the rocket insertion tool was not used.

Space Between Wing Stores

It was observed that when the 19-tube rocket launcher was placed on the outboard rack, it restricted the movement of the loader around the missile launchers. This situation would appear to complicate the loading task. The loaders did not complain of the "tight" space, and no attempt was made to obtain missile-loading times without the rocket launchers in place or with two HELLFIRE launchers on the same side.

Stray Voltage Check

At the time of the investigation, precise procedures were not available for using the MARK IV modified tester for checking both missile and rocket system stray voltages. In addition, personnel involved with the operational testing of the AH-64 were using a voltmeter to check stray voltage on the rocket system, apparently because it was more sensitive.

Loading Time

An analysis is contained here to show that the loading time can be significantly reduced by positioning the ordnance as close as possible to the aircraft. As an example, the time to load missiles can be separated into three events: extraction time, transit time, and attaching time. The extraction time is the time to unlatch the container and lift the missile free; the transit time is the round-trip walking time between the container and the launcher; and the attaching time is the time to attach the missile to the launcher rails. The three-man team loaded eight missiles in 4.40 minutes with the containers placed outside of the rotor diameter approximately 38 feet from the launchers. Each missile can therefore be loaded in 0.55 minutes. When the extraction time of 0.12 minutes and transit time of 0.17 minutes are subtracted from the loaded time, the resulting attaching time is 0.26 minutes per missile.

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If procedures would permit the helicopter to land with the containers 12 feet from the launchers, the transit time would be reduced to 0.05 minutes per missile and 8 missiles could possibly be loaded in 3.44 minutes. This is a 22-percent savings in time.

By a similar analysis, the time to load 38 rockets could be reduced to 2.76 minutes from 4.68 minutes, a 41-percent savings in time. As a result, the time to load ordnance would be reduced from 8.90 minutes to 6.20 minutes, which is a 30-percent savings in time because of the 68-percent reduction in walking distance.

Crew Comments

At various times during the data collection trials, the subjects were interviewed to get their thoughts and comments on the procedures established and equipment design issues. The following summarizes their comments:

A. Though they do not possess the MOSs identified for FARP personnel, they felt it would be easy to train an individual to perform the required tasks. It was estimated that this training would take less than one week.

B. There are times when the fueler is changing tanks that interference with the weapon loaders occurs.

C. The M-17 mask was difficult to work with. When looking downward, the mask and hence the eyeholes tend to rise up. Subjects reported they were sometimes looking cross-eyed.

D. It was difficult to open the gravity port fuel cap while wearing CB gloves.

E. When two different-sized people are teamed up to load the HELLFIRE missiles, the largest person should always be at the missile front. This will facilitate any need for moving between the pylons.

F. The subjects felt it would be very fatiguing to rearm and refuel more than one aircraft consecutively. This is especially true when wearing CB protective clothing.

G. The following are areas for improvement identified by the subjects:

1. A new design for attaching the HELLFIRE missiles to the launcher rail is desirable.

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2. The method of locking the missile should be changed. Perhaps, an automatic system could be devised.

3. Consideration should be given to changing the loading sequence. That is, load the lower missiles first.

4. Provide a new CB mask which will allow greater vision.

5. Paint all missiles with the textured finish. This allows for better handling than the smooth finish.

6. Improved means of removing the HELLFIRE missiles from the new container are desirable.

CONCLUSIONS

A. From the analysis, it can be concluded that all three conditions evaluated did have an impact on rearming and refueling times. The crew-size change appears to have the most impact, followed by the day/night condition, and then the wearing of CB protective clothing.

1. Crew Size. The three-man crew consisted of two weapon loaders and one fueler. The five-man crew consisted of four weapon loaders and one fueler. The crew loaded 8 HELLFIREs and 38 2.75-inch rockets and simulated refueling.

a. Based on preliminary data, it is envisioned that loading the 30mm chain gun will take at least as long as loading the rockets. Hence, the three-man crew will not be able to meet the ten-minute turn-around time to load 8 HELLFIRE missiles and 320 rounds of 30mm ammunition and refuel as specified for the AH-64 in AMC-SS-AAH-H10000A.

b. A five-man crew may be able to meet this ten-minute turn-around time if 30mm reloading is conducted simultaneously with HELLFIRE missile reloading.

2. Day and Night Conditions Effects

a. There is an increase of 38 percent in the rearming and refueling time for a five-man crew at night over that during the day.

b. There is an increase of 36 percent in the rearming and refueling time for a three-man crew at night over that during the day.

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3. Chemical and Biological Protective Clothing Effects

a. There is an increase of 7 percent in the rearming and refueling time for a five-man crew with CB gear over that without CB gear.

b. There is an increase of 16 percent in the rearming and refueling time for a three-man crew with CB gear over that without CB gear.

Note: The above data were taken under environmental conditions which were not severe enough to induce heat stress.

This data is summarized in Figure 1.

B. FARE Equipment

1. FARE equipment may not be capable of delivering 50 gal/min to two aircraft simultaneously using the current pumping system. Therefore, excluding 30mm considerations, refueling may be a longer process than rearming.

2. Two FAREs will be required for each FARP. The placement of a FARE on vehicles/trailers may enhance fuel availability to the aircraft.

C. HELLFIRE Missiles

1. The interface between the HELLFIRE missile and the launcher rails does not facilitate ease of loading. This is particularly true at night or when the crew is wearing CB protective clothing.

2. The design of the newer metal container makes it very difficult for the crew to extract the missiles. It is extremely difficult, if not impossible, for the missile to be extracted from the container without handling the fins, forward attaching shoe, or optical seeker head.

D. 2.75-inch Rockets. Given the fact that the new 19-rocket containers weighing about 575 pounds will come packed two to a pallet, consideration needs to be given as to how these containers will be moved around the FARP area.

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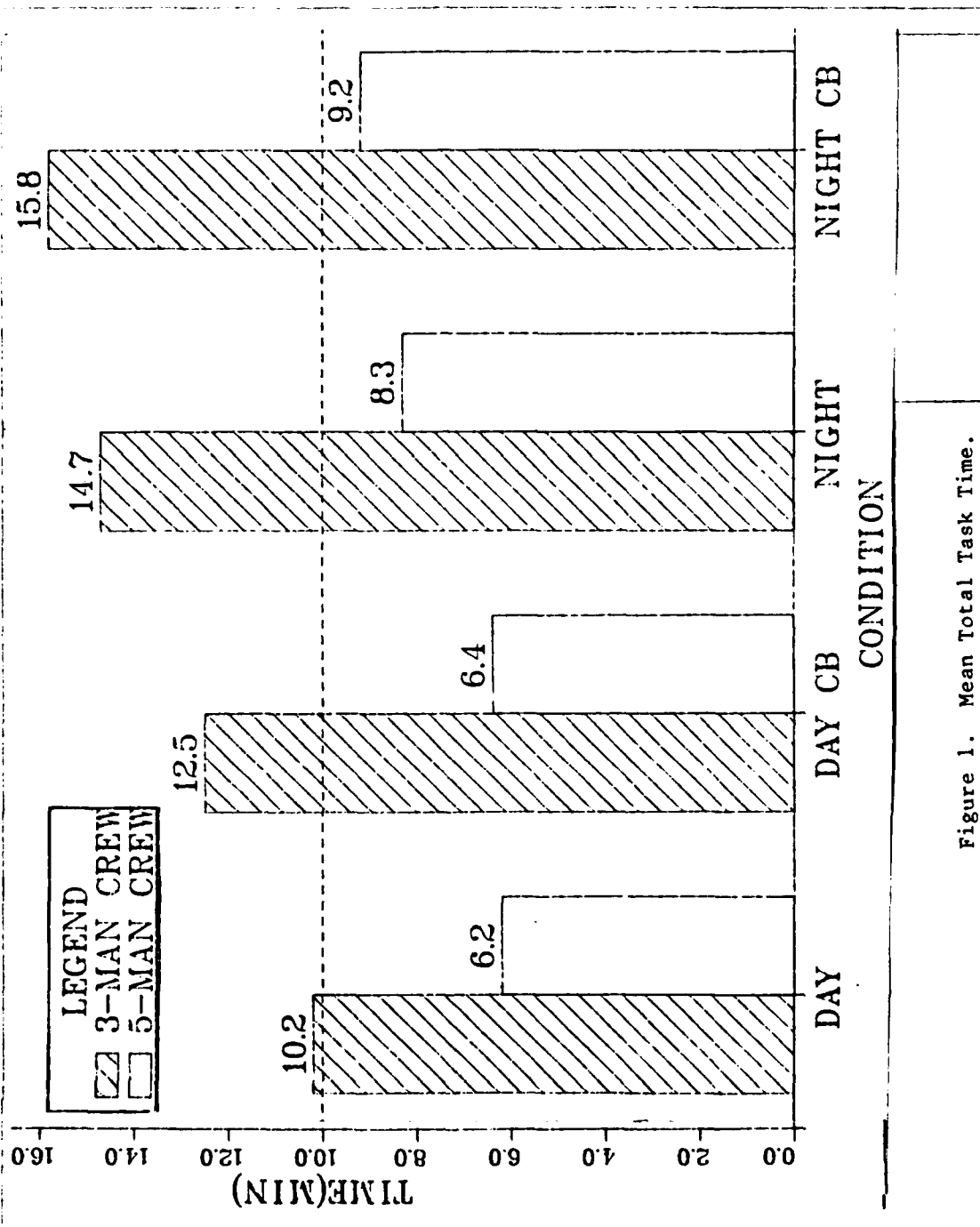


Figure 1. Mean Total Task Time.

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RECOMMENDATIONS

Based on the FARP evaluation effort accomplished to date, it is recommended that the following issues and areas of future investigation be addressed in order to be able to fully assess the impact of operating in FARPs.

A. A similar investigation be repeated on an actual aircraft to determine the degradation due to a turning rotor blade, blowing dirt and grass, and the reduced ability to communicate due to the high noise environment.

B. A similar investigation be conducted under environmental temperature conditions expected on the battlefield to assess the crews' ability to perform under more realistic conditions.

C. Conduct an assessment of the time required to rearm the 30mm cannon in the forward area.

D. Assess the implications of performing simultaneous rearming and refueling. Similarly, assess the possibility of rearming missiles and rockets at the same time the 30mm cannon is being rearmed.

E. Evaluate the turn-around time for an entire attack team comprised of five attack and three scout helicopters.

F. Evaluate the impact on turn-around time of the following factors:

1. General maintenance performed on the aircraft.
2. Personnel performing duties outside of their MOS.
3. Additional crew size variations.
4. Aircrew personnel assist the rearming and refueling effort.

G. Develop a computer model of FARP operations. This would allow rapid assessment of the impact of varying certain parameters on rearm and refuel turn-around times.

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